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Innovative design: developing strategies to improve developer attitudes to sustainable housing

Abstract: *The literature advocates more widespread adoption of a particular type of house – a manufactured high performance green house and/or house components (MHPGH) and this is the focus of the research proposal outlined in this conceptual paper. The aim of the current paper is to outline a robust program of work to improve adoption of MHPGH. The contribution of houses to climate change is investigated, the conservatism of the construction industry is documented, a conceptual framework through which to understand the problem is presented; a program of research to bring about change is outlined; and the benefits of doing so are summarised. The contribution of the paper is the presentation of novel theory and methods to address sustainability problems in the construction industry. Future work will involve execution of the proposal. A limitation of the paper is that the effectiveness of the proposed theory and methods are yet to be tested.*

Keywords: manufactured housing, innovation, theory, model

Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that greenhouse emissions from building energy consumption worldwide can be reduced by 30% at no net cost, by 2020 [1]. Manufactured high performance green houses (MHPGH) are thus a particularly promising housing innovation as they contribute to this target. Following Kibert [2, p.9], we define MHPGH as "*healthy prefabricated houses designed and constructed using ecological principles, reaping efficiency and quality improvements through production in a factory-controlled setting.*" This represents a necessary paradigm shift away from traditional, inefficient, onsite production. The incidence of MHPGH is currently low in Australia and most overseas countries [3, 4], with no comprehensive research into the reasons for this poor uptake. Research on energy use has often focused on high-profile sectors such as coal mining and transport, ignoring the building industry's significant impact [5]. Housing research in Australia has similarly overlooked environmental sustainability in its research priorities [6]. The goal of the proposed research is to address these gaps and improve the adoption of MHPGH by the housing industry, with a specific focus on understanding the beliefs of building contractors.

Scope

MHPGH are taken here to comprise: (1) whole single dwellings (e.g. prefabricated transportable housing); (2) whole multiple dwellings (e.g. containerised building); (3) manufactured individual pods (e.g. bathrooms, kitchens or living areas that can be interlinked to create a complete dwelling); and (4) structural insulated panels.

Background

Historically, the demand for manufactured buildings was driven by the need for low-cost, speed and mobility, with little regard for whole-of-life performance. Such buildings were typically constructed to minimum quality standards and supplied to niche sectors such as mining camps, schools, tourist parks and post-war rebuilding [7]. Modern MHPGH are produced in a factory-based setting using advanced manufacturing technologies. MHPGH promise improved environmental impact and lower costs compared to on-site production of houses through closer regulation of CO_2 emissions; greater integration of design and construction; improved reuse of construction materials through standardised connection systems, and reduced waste driven by tighter production controls [8]. Contemporary MHPGH therefore need to overcome the incongruous history of low quality, low performing manufactured buildings.

Significant change in house construction techniques will be required to maximise the impact of MHPGH. The construction industry generally, and house production in particular, has a poor innovation performance globally [9]. Introducing manufacturing processes can play a key role in promoting a more innovative industry as manufacturers typically spend far more in research and development than contractors or designers [10]. The beliefs of building contractors towards the introduction of these new processes comprises a major determinant of the impact of house construction on the serious problem of climate change [11]. The design and construction of houses play a large role in determining the scope for occupiers to minimise energy consumption over the house's lifespan. There is an awareness that stricter building regulation alone has a limited ability to increase innovation in the housing industry, as emphasised by recent global studies emphasising the need to also encourage more positive attitudes to innovation [12].

The core problem is the conservative nature of the construction industry, as has been highlighted by major government inquiries [13]. There are negative attitudes within the construction industry towards the value presented MHPGH, with building professionals underestimating their contribution to greenhouse gas emissions and overestimating the cost premium associated with green building methods [4, 14].

Conceptual framework

To investigate these issues, we conceptualise the housing industry as an Open Innovation System [15]. We call this model the Housing Innovation System for MHPGH. Our new model extends existing theory, by combining Gann and Salter's [16] Project-Based Product Framework (PBPF) with the Theory of Planned Behaviour (TPB) [17] and Technology Acceptance Model (TAM) [18]. Open Innovation Systems are currently the most widely employed model of innovation systems, drawing on earlier models focused on innovation milieu, complexes, districts and networks [19]. The concept is simple to understand and persuasive in its call for greater openness to external ideas, in the name of creativity, innovation and growth [20]. This central idea of openness to new ideas generated by other people or firms is particularly relevant to the problem of increasing the adoption of MHPGH, as the whole construction supply chain needs to be on board. As the Open Innovation System approach provides only general guidance, the PBPF provides a structure for describing the innovation system [21], given that the construction production is project-based. An extended version of the PBPF will be employed to describe the participants and activities within the system, providing a rich context for our study of decision-making processes underpinning adoption. This is the first time the PBPF will be used to explore an Open Innovation System.

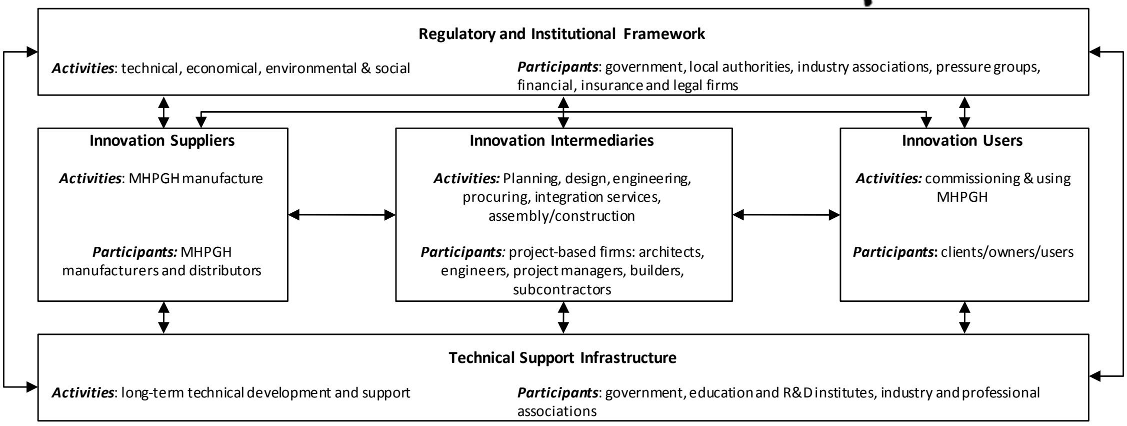

Figure 1: Extended Project-Based Product Framework (PBPF), based on Gann and Salter [16].

The model presented in Figure 1 is based on the main analytical dimensions of the PBPF, except we have conceived the dimensions directly involved in housing projects to be part of a three-stage innovation supply chain, comprising suppliers, intermediaries, and users. The arrows show the flow of knowledge and beliefs. The latter, beliefs, are a new analytical dimension. The study focuses on the role of builders and their beliefs. They will be asked about the roles of MHPGH suppliers, home buyers (innovation users), the regulatory and institutional framework, and the technical support infrastructure.

TPB and TAM. The TPB and TAM together comprise a comprehensive framework for understanding individual decision making, which will be applied to describe the nature of beliefs within the Housing Innovation System for MHPGH. TPB is a general theory of human behaviour, traditionally applied to health problems, but increasingly applied to the adoption of technology and innovation. The model suggests that the immediate predictor of MHPGH adoption behaviour is the intention to adopt, in turn predicted by attitudes, subjective norm (pressure applied by influential people) and perceived behavioural control (external factors the encourage or impede the behaviour). As this psychosocial model is being applied to an industrial context involving technological change, it is useful to extend it to incorporate technological characteristics; this is achieved by incorporating the TAM model.

TAM is an influential and commonly employed theory about user attitudes to new technologies [22]. It is often integrated with the TPB by considering the impact of ‘perceived usefulness’ and ‘perceived ease of use’ as predictors of the TPB attitudes component.

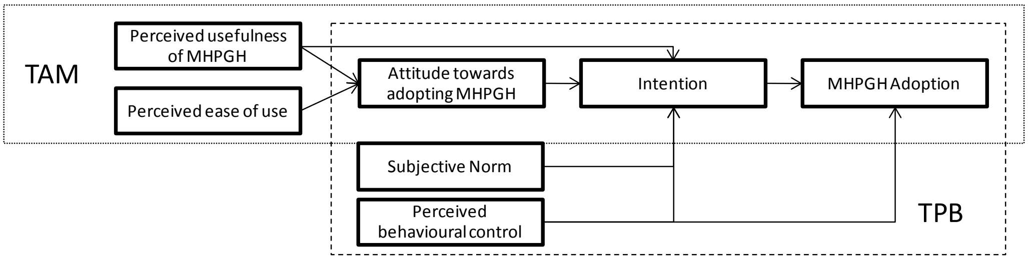

Figure 2: Integrated Theory of Planned Behaviour (TPB) and Technology Acceptance Model (TAM) - based on Wu and Chen [23]

The TPB and TAM are both well validated models that have been used separately and together to explain key influences on intentions and behaviour [24]. This study will be the first application of this integrated model to explain behaviour in an Open Innovation System, and in the housing industry. The study will employ multiple levels of analysis, through looking at the decision-making of *individuals* working on *projects* in the context of the Housing Innovation *System* for MHPGH.

Novelty of Approach

The proposed study is important because it advances conceptual knowledge in four key areas.

(1) Conceptualisation of an industry: The model of the Housing Innovation System for MHPGH expands on the conventional conceptualisation of an industry by the statistical agencies of many countries, and by the authors of many reports into industry practice [25]. The proposed approach considers a much broader array of participants and innovation determinants, reconceptualising the 'industry' as a 'system.' This involves considering the vertical and horizontal supply chain relationships radiating from traditional industries such as building construction, construction services, public administration and tertiary education [26].

(2) Conceptualisation of an Open Innovation System: The identification of innovation constraints in project-based environments has been hampered by the lack of nuance in existing Open Innovation System theory. The integration of the PBPF, TAM and TPB will add substance to the Open Innovation System model. This will address the criticism that core concepts are underdeveloped, especially the impact of different degrees and types of openness [21, 27, 28]. The current proposal responds to this criticism by focussing on the attitudes of system participants as a particular type of openness.

(3) Conceptualisation of project-based activity: The Open Innovation System model has mostly been applied to high technology manufacturing sectors in the past. Previous work by the first author comprises the first significant study of its application in a project-based environment in 2010 [29]. The current study extends this work to the housing sector.

(4) Conceptualisation of construction innovation: Existing models tend to focus on the suppliers of construction innovation, taking a mechanistic firm-level innovation management approach [30, 31]. The proposed research differs by taking a broader approach and accounting for the 'messy' nature of innovation in project-based industries [32]. The research does this by unpacking control issues through TPB/TAM and accounting for system complexity through the PBPF.

Methods

We build on suggestions in the global literature that builders' misconceptions drive the low adoption of MHPGH by undertaking a comprehensive evaluation of their beliefs regarding:

1. outcomes from implementing the innovation (e.g. cost, quality, environmental)
2. effort required to achieve the outcomes (e.g. adapting to a new production system)
3. pressure applied by important people (e.g. professional association leaders/members)
4. value placed on the opinions of important people (e.g. cost of moving against the tide)

5. external conditions that affect adoption (e.g. suppliers, legislation, knowledge)
6. power over external conditions (e.g. relationships, capabilities)

Phase 1 will develop the Housing Innovation System for MHPGH Map (6 months). The fieldwork program will break new ground. There is currently no comprehensive data on the size, age, distribution or scope of the manufactured housing sector in Australia. An accurate and up-to-date understanding of the structure of the Housing Innovation System for MHPGH (see Figure 1) is needed for the study of belief systems. Phase 1 will comprise a desk-top investigation combined with snow-ball sampling.

Phase 2 will be a Qualitative Study of Beliefs (6 months). Following the procedure developed by Ajzen [33] this phase will qualitatively examine the beliefs of Australian builders in the Housing Innovation System for MHPGH. They will be recruited to take part in interviews and focus groups to identify the key obstacles to innovation adoption. The data collection will be guided by a set of semi-structured questions to elicit salient beliefs. For example “What are the advantages of using MHPGH?”, “Which individuals or groups think you should use MHPGH?”, and “What might discourage you from using MHPGH?” The research will use content analysis of focus group transcripts and notes to identify the most frequently occurring beliefs.

Phase 3 will be a Quantitative Study of Intentions (6 months). MHPGH adoption intentions and behaviour will be framed according to Ajzen’s [33] recommendations concerning target, action, time and context. This rigorous definition will result in a target behaviour definition such as ‘Adopting MHPGH innovations on at least one housing project over the next three months.’ Based on the TPB, we predict that builders will have stronger intentions to use MHPGH when they: (1) hold a positive attitude towards MHPGH, (2) perceive support from influential persons or groups around them, and (3) perceive that adopting MHPGH is easy to do and within their control. The researchers will randomly survey 1600 registered builders, with an expected 530 respondents (30% response rate). Survey participants will rate the strength of their agreement with statements about factors that might influence their decision to use MHPGH. These statements will be based on the key influences identified in Phase 2. The quantified and ranked results will be used to develop an educational program aimed that the key drivers of intentions uncovered by the research, to increase adoption of MHPGH.

Conclusions

This is time-critical research, as moving MHPGH into the mainstream must happen now if we are to effectively address the challenge of climate change [2, 5]. Indeed, the research will lead to a broad range of potential benefits. The environmental benefit will be house construction which produces less waste and uses less energy than current practice. The economic benefit will be a more efficient housing industry through off-site manufacture. The social benefit will be high performance housing, driving superior living conditions for occupiers. The housing industry has a significant impact on living standards, but because it is a traditional industry, lacking the glamour of research-intensive industries, the construction sector has received limited attention from innovation analysts. This proposed study will fill this research gap, and provide greater economic, environmental and social returns from house construction than those available from existing industry practice. The contribution of this paper has been the presentation of novel theory and methods to address sustainability problems in the construction industry. Future work will involve execution of the proposal. A limitation of the paper is that the effectiveness of the proposed theory and methods are yet to be tested.

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